Aromatic Hydrocarbon Adsorption Characteristics of Disposable Filtering Facepiece Respirators that Contain Activated Charcoal

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Objective

The objective of this pilot study was to investigate the aromatic hydrocarbon adsorption characteristics of nuisance organic vapor filtering facepiece respirators (FFRs).

Background

- Particulate matter (including viable bacteria/viruses, virus/blood fragments, etc.) and nuisance levels of volatile organic compounds (VOCs) are released during surgical procedures conducted with lasers and electrosurgical devices.
- For over 30 years healthcare workers (HCWs) have expressed concerns regarding these exposures to surgical smoke, including complaints of headaches, nausea, irritated throat and lungs and asthma. Over 500,000 HCWs are exposed to surgical smoke every year.[1]
- HCWs use a variety of personal protective equipment (PPE) to reduce their exposure to occupational hazards, including FFRs to reduce inhalation of infectious bioaerosols. However, FFRs are designed to protect the wearer from particulate hazards and not gases or vapors.
- Both the Institute of Medicine and the National Occupational Research Agenda (NORA) (Healthcare Sector) have recommended research to develop PPE that meets the needs specific to HCWs. NORA has requested research that leads to a reduction in HCW exposure to surgical smoke because of its mutagenic potential and its impact on eyes and the upper respiratory tract.

- Industrial workers sometimes use nuisance organic vapor FFRs that contain activated charcoal because they are marketed as FFRs that provide odor control and increase worker comfort. However, no data has been published describing the ability of these FFRs to capture organic vapors and they are not certified by NIOSH for this purpose. Exploring the adsorption capability for thin activated charcoal layers may be advantageous to developing a respirator that addresses concerns raised by HCWs.

Methods

Three FFR models were tested to determine the 10% breakthrough time for VOCs found in surgical smoke. Benzene, Toluene and Xylene are known as aromatic hydrocarbons, a class of VOCs. Prior to testing, each respirator was sealed to an ISI headform which was then enclosed in an acrylic chamber (15x15x15 inches). A Valco M6 liquid handling pump delivered a pre-set volume of VOC into a heated brass block where it was dispersed into a Miller Nelson (model HCS 401) generated airstream. All respirator models were exposed to each vapor separately (20 ppm, 37 LPM) in three duplicate tests (n=27). Periodically, gas samples were directed to an SRI Gas Chromatograph (Model 8610C) for analysis (Figure 1).

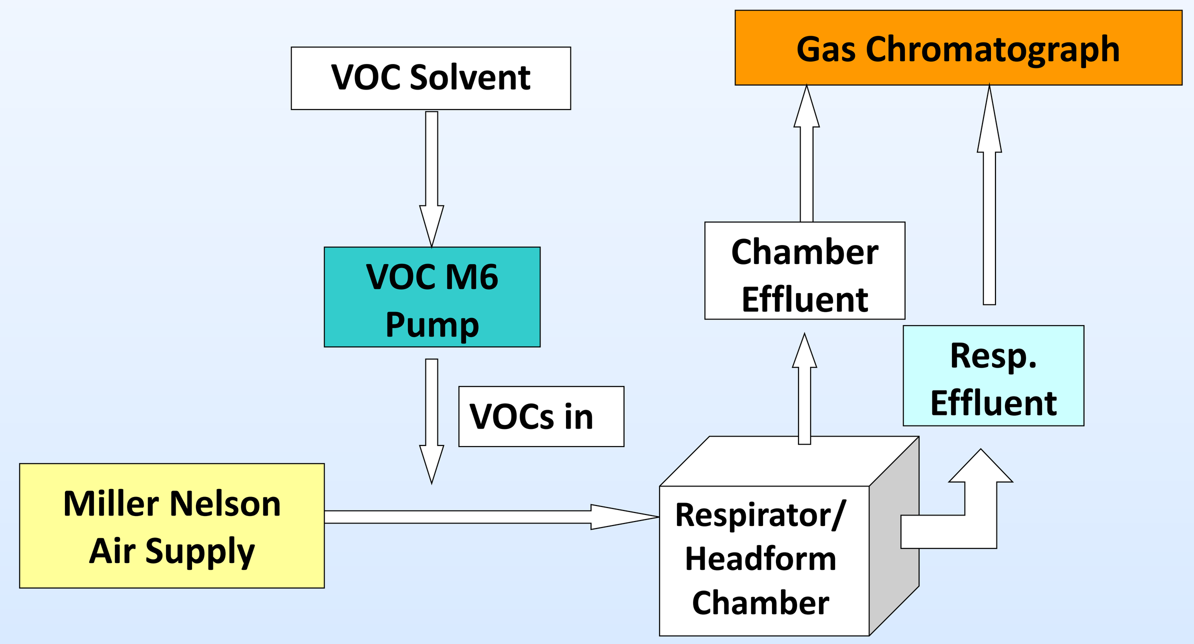

Figure 1. Apparatus configuration to determine the volatile organic compound adsorption capabilities of disposable FFRs.

The experimental results were then used to predict breakthrough curves for model Respirator B for a 30 ppm challenge concentration of Toluene with the following Yoon equations: $t = \tau + \frac{1}{k'} \ln\left(\frac{C_b}{C_i - C_b}\right)$ (eq. 1)[2] and $\frac{\tau_2}{\tau_2} = \left(\frac{C_1}{C_2}\right)^a$ (eq. 2)[3], where τ represents the 50% breakthrough time for a given challenge concentration, C_i is the test concentration, C_b is the breakthrough concentration, t represents time, and values a and k' are determined experimentally from tests at 10 and 20 ppm.

Results

Table 1. Breakthrough times for three challenge volatile organic compounds at 37 LPM.

Respirator	Respirator Properties	VOC (20 ppm)	Average BT^ Initial (min)	Average BT^ 10% (min)	10% BT Range (min)
A	N	Benzene	46	90	77 – 90
	Valve	Toluene	83	119	117 - 131
	5.0 g*	Xylene	98	150	147 - 163
B	R	Benzene	68	82	67 – 86
	No Valve	Toluene	45	115	112 - 118
	3.1 g*	Xylene	0	131	128 - 134
C	P	Benzene	45	66	64 – 70
	Valve	Toluene	4	96	93 - 97
	2.5 g*	Xylene	2	111	102 - 118

***Estimated weight of the activated charcoal according to the manufacturers ^ BT is breakthrough time**

Results

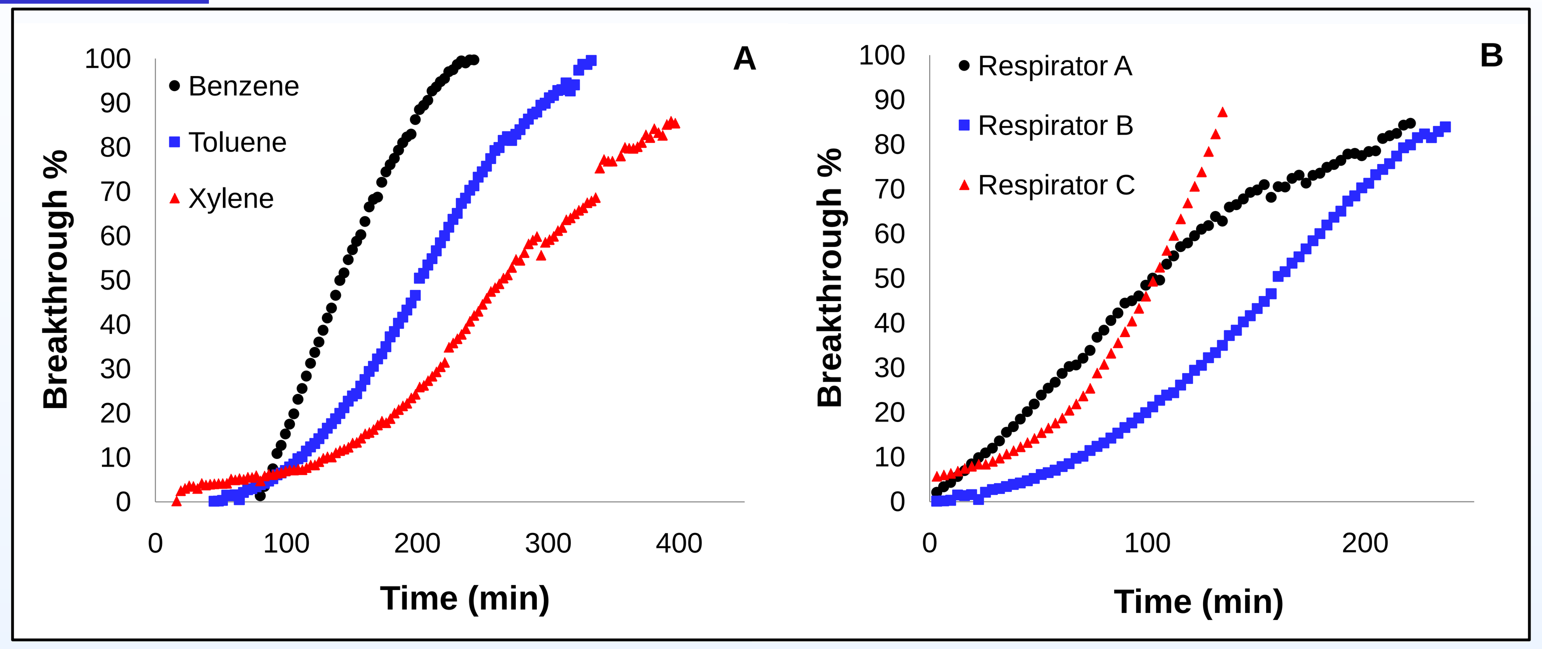

Figure 2. Graph A shows typical breakthrough curves for model Respirator A for the tested challenge VOCs at 20 ppm. Graph B shows typical breakthrough curves for 20 ppm of Toluene for each tested respirator.

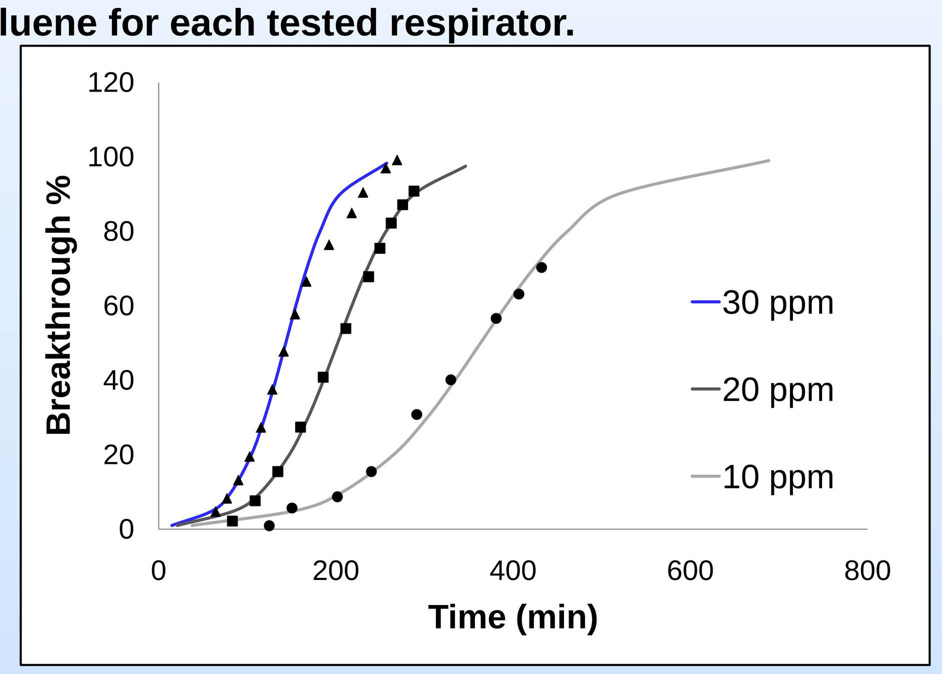

Figure 3. Predicted Toluene breakthrough curves on model Respirator B at a flow of 37 LPM with experimental data (points) measured at 10, 20 and 30 ppm respectively. The 30 ppm curve (blue) was predicted from tests performed at 10 and 20 ppm.

Conclusions

- All FFRs maintained 10% breakthrough time of at least 1 hour.
- One model prevented the near-instantaneous breakthrough of Toluene and Xylene, suggesting a minimum amount of activated carbon may be necessary.
- The lack of a standard for evaluation of the performances of these devices contribute to the variability observed.
- Technology available in nuisance organic vapor FFRs may be applicable to the healthcare sector.
- Future research is needed to confirm that properly fitted nuisance organic vapor FFRs designed to mitigate odors during industrial processes could reduce HCW exposure to low level nuisance VOCs.

References

1. Ulmer B C. The hazards of surgical smoke. AORN J. April 2008; 87(4):721-734.
2. Yoon YH, Nelson JH. Application of gas adsorption kinetics I. A theoretical model for respirator cartridge service life. Am. Ind. Hyg. Assoc. J. 1984; 45(8):509-516.
3. Yoon YH, Nelson JH. Application of gas adsorption kinetics II. A theoretical model for respirator cartridge service life and its practical applications. Am. Ind. Hyg. Assoc. J. 1984; 45(5):517-524.